Atmospheric Environment 42 (2008) 8412–8421

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Comparing air quality in Italy, Germany and Poland using BC indexes

Olha Bodnar [b], Michela Cameletti [a], Alessandro Fassò [a,*], Wolfgang Schmid [b]

[a] Department of Information Technology and Mathematical Methods, University of Bergamo, Via Marconi 5, 24044, Dalmine (BG), Italy
[b] Department of Statistics, Europa Universität Viadrina, Frankfurt (Oder), Germany

ARTICLE INFO

Article history:
Received 24 April 2008
Received in revised form 21 July 2008
Accepted 12 August 2008

Keywords:
Particulate matters
Tropospheric ozone
Environmental time series
Unbalanced monitoring networks
Network heterogeneity index

ABSTRACT

In this paper we discuss air quality assessment in three Italian, German and Polish regions using the index methodology proposed by Bruno and Cocchi. This analysis focuses first of all on the air quality in each of the considered countries, and then adopts a more general approach in order to compare pollution severity and toxicity. In this context, air quality indexes are a powerful data-driven tool since they are easily calculated and summarize a complex phenomenon, such as air pollution, in indicators which are immediately understandable. The use of a unique index should be encouraged in a global European perspective where all countries are commonly involved in assessing air quality and taking proper measures for improving it. In particular, the main objective of this work is to evaluate the index performances in distinguishing different health risk related air pollution patterns.

1. Introduction

Air quality is known to be an important issue for both governments and citizens. On one hand, the latter are interested in detailed and timely air quality information regarding their own country. For example, the European Environment Agency (2007) gives detailed behavioral hints for high tropospheric ozone events. On the other hand, the EU member states have to comply with European and national directives, which fix limit values and alert thresholds for the main air pollutants and provide criteria and reference methods for measuring them. On this subject, see the EU Council Directive 1999/30/EC, relating to pollutant limit values, and the EU Council Directive 1996/62/EC, on ambient air quality assessment and management.

In this framework a simple and effective tool, such as an air quality index, is needed for giving timely information about air quality in order to assess compliance with reference standards and evaluate the effects of emission control policies. Air quality indexes are easily computed and synthesize multiple and multiscale measurements in a standardized indicator that provides timely and easily understandable information. Their use is suggested, for example, by the U.S. Environmental Protection Agency (EPA) which publishes national guidelines for their computing and reporting (U.S. EPA, 2003).

Although the European directives define the measurement methods for various pollutants, there are differences among the national monitoring networks in terms of spatial distribution of the different instruments and, hence, of the monitored pollutants. Moreover, especially with long time series and trend analysis, network characteristics change both in space and time, thus giving rise to heterogeneous networks (Fassò et al., 2007).

From the scientific investigation point of view, air quality indexes can be used for preliminary analysis in air quality spatio-temporal modeling and mapping or in impact assessment of air pollution exposure (Bellini et al., 2007; Englert, 2004; Pope, 2000). Moreover, indexes can be used as sub-indicators in composite indicators, see e.g. Saisana et al. (2005) and references therein. Recently Lagona (2005) and Chiu et al. (revision submitted) have proposed an approach to indexes by means of the latent factors of a Hidden Markov Model. Although it is

* Corresponding author. Tel.: +39 035 205 2323; fax: +39 035 562 779.
E-mail address: alessandro.fasso@unibg.it (A. Fassò).

1352-2310/$ – see front matter
doi:10.1016/j.atmosenv.2008.08.005

Table 1
Information about the pollutants under consideration

Pollutant	Measurement unit	Temporal aggregation function	Standard limit ($\mu g\,m^{-3}$)
C_6H_6	$mg\,m^{-3}$	Daily average	$10 mg\,m^{-3}$
CO	$\mu g\,m^{-3}$	Daily max of 8-hours moving averages	$10 \mu g\,m^{-3}$
NO_2	$\mu g\,m^{-3}$	Daily maximum	$300 \mu g\,m^{-3}$
PM_{10}	$\mu g\,m^{-3}$	Daily average	$50 \mu g\,m^{-3}$
O_3	$\mu g\,m^{-3}$	Daily max of 8-hours moving averages	$120 \mu g\,m^{-3}$
SO_2	$\mu g\,m^{-3}$	Daily average	$125 \mu g\,m^{-3}$

a promising approach, simplicity and interpretability are still under study and we opt here for explicit index definition.

In this work, we use the BC index methodology proposed by Bruno and Cocchi (2002, 2007) for assessing and comparing air quality in three areas of Italy, Germany and Poland. These countries are known to have different geo-meteorological characteristics and different population densities giving also markedly different pollution levels. Hence, it is interesting to understand to what extent a BC index can point out seasonality and discriminate among different air pollution patterns. In particular, the case of heterogeneous monitoring networks is discussed with reference to the BC indexes showing which one is preferable for comparing perspectives. The structure of the work is the following: in Section 2, we present the Italian, German and Polish regions under consideration together with some relevant geographical, meteorological and anthropic characteristics. Moreover, the monitoring networks used in year 2005 are discussed in terms of the spatial distribution of stations and pollutant sensors. In Section 3, we introduce the notation and methodology of BC indexes for health risk oriented air quality analysis. The results are given in Section 4, where the obtained index time series are widely discussed within and between the considered areas. In particular, focusing on the index performance in terms of the capacity of distinguishing different air pollution situations, we show how the indexes are related to the monitoring network structure.

2. Data description

The index analysis is referred to the year 2005. It is carried out on the Piedmont and Lombardy regions in Italy, on the Berlin and Brandenburg states in Germany and on the Masovian Province in Poland. We discuss the three cases in the following subsections.

Following the above mentioned European directives, we consider the pollutants listed in Table 1 together with the corresponding standard limit values and the temporal aggregation functions used for the indexes of Section 3.

The considered pollutants are related to industrial, domestic and traffic sources. In particular sulphur dioxide (SO_2) is an "old pollutant" as it is mainly the result of the burning of coal which has been replaced in most European countries; nevertheless it is still monitored because of its potentially high impact on both humans and the environment.

Nitrogen dioxide (NO_2), carbon monoxide (CO) and benzene (C_6H_6) are strongly related to combustion, road traffic and petrol distribution.

Particulate matters (PM_{10}) with an aerodynamic diameter lower than 10 μm are related to vehicle traffic and house heating. Although ultrafine particulate matters ($PM_{2.5}$ and PM_1) are known to be more dangerous for human health, the corresponding measurements have not been included in this analysis because they were scarcely monitored for the year under consideration.

Finally, tropospheric ozone (O_3) is a secondary pollutant produced by reaction between nitrogen dioxide, hydrocarbons and sunlight. It is known to be especially high on sunny hills and mountains around areas with a high density of traffic, as in Italy, and has a very skewed distribution and complex dynamics, see e.g. Fassò and Negri (2002).

2.1. Italian region

The regions studied are Piedmont and Lombardy. They cover an area of 49,260 km^2 in the western part of the so-called Po Valley in the North of Italy, as shown in Fig. 1. The area stretches for about 300 km in an east-west direction and is surrounded by the Alps on the northern and western

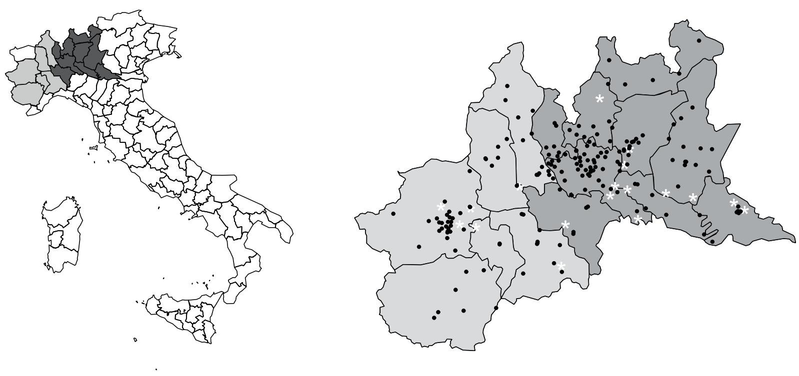

Fig. 1. On the left: location of Piedmont (western, light gray) and Lombardy (eastern, dark gray). On the right: pollutant monitoring network (white stars for rural stations and black dots for urban ones).